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# Using Electric Motors to Explore Conservation of Energy Concepts

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# Using Electric Motors to Explore Conservation of Energy Concepts

Finn Buldt, Jonathan Howard, Skyler Stauffer, Jacob Millspaw, Ph.D., and Mark F. Masters, Ph.D.,

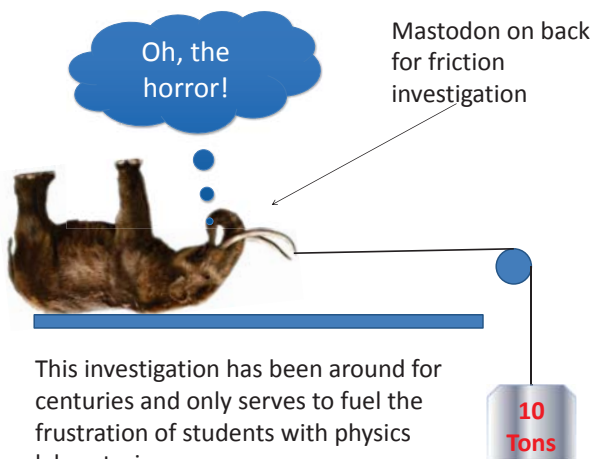
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## Work - Energy is difficult to explore in laboratory

The laboratory is a special opportunity to learn by exploration. However, when it comes to energy, most laboratory investigations could just as well be done using forces and kinematics as using work energy principles.

At the 2011 Winter AAPT meeting we presented one method of making work measurements using a fan cart that turned on and off over a fixed distance, allowing exploration of the work – kinetic energy theory (see [http://opus.ipfw.edu/physics\\_facpres/44/](http://opus.ipfw.edu/physics_facpres/44/)). This year, we turn our attention to gravitational potential energy and work by friction.

A classic (and rather horrible) introductory investigation of friction involves pulling a “sled” along a ramp to determine the coefficient of kinetic friction. There is generally the requirement that you put enough weight hanging over the edge of an incline that the cart moves with roughly constant speed after giving the cart a slight tap.



This investigation has been around for centuries and only serves to fuel the frustration of students with physics laboratories.

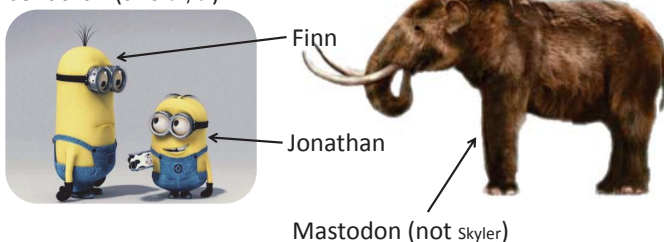
So why not investigate this using work energy?

## How to force student use of work – energy!

Our original idea was to use electric shock. However, the Institutional Review Board (IRB) shot that proposal down. So we had to settle for second best.: and electric motor

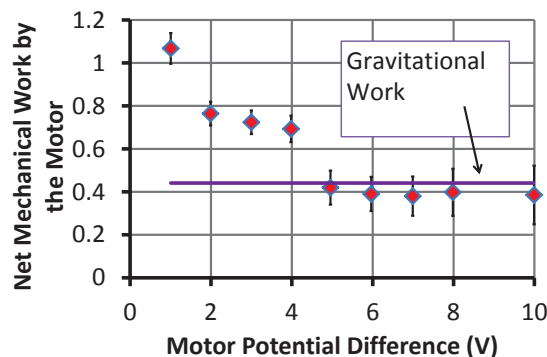


The motor drags a “sled” along a plane. If we can just figure out how get the energy used to drag the “sled,” we have it made. Also, we need a couple of minions to make measurements and do all the hard work. Enter Finn and Jonathan (and Skyler)



Using a gearhead DC motor we performed multiple vertical lifts of known masses, a known height. We varied and measured the potential difference across the motor and the current of the motor, loaded and unloaded, and the time to lift the weight. We assumed that the largest losses in the motor are frictional and constant. Therefore,

$$(P_{\text{Loaded}} - P_{\text{unloaded}}) \times T = \text{Work}$$

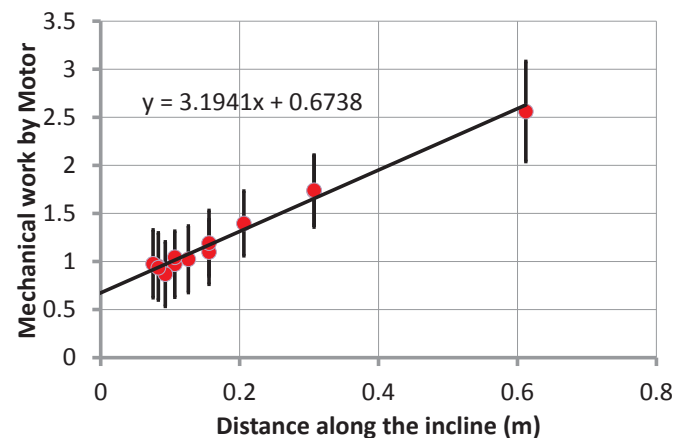


As shown in the figure, as we apply higher potential differences, the difference between the loaded and unloaded powers approaches the rate of mechanical work, validating our previous assumptions

## A second experiment: determine the coefficient of friction on an incline.

In our second investigation, we used an incline and a loaded sled. The motor dragged the weights up the incline. We kept the height constant so that the gravitational work is a constant:

$$(P_{\text{loaded}} - P_{\text{unloaded}}) \times T = \mu mgL + mgh$$



The plot of the mechanical work vs. the distance along the incline (we varied incline angle), results in a straight line. The intercept being equal to  $mgh$  or the constant change in potential energy. From the intercept we calculate the weight of the sled as 12.5 N  $\pm$  0.9N in agreement with the value used (11.7N). The coefficient of friction is calculated as 0.27  $\pm$  0.05.